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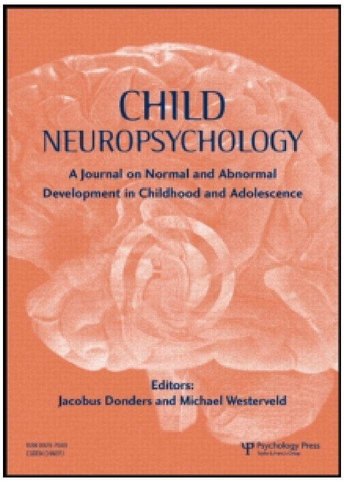

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Inhibitory Deficits in Reading Disability Depend on Subtype: Guessers but not Spellers*

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ABSTRACT

In this study, children with the guessing subtype of dyslexia (who read fast and inaccurately) were compared with children with the spelling subtype (who read slowly and accurately) on three aspects of executive functioning (EF): response inhibition, susceptibility to interference from irrelevant information, and planning. It was found that guessers were impaired in their ability to inhibit inappropriate responding on all tasks used to assess EF (the stop signal task, the Stroop task, and the Tower of London task). This raises the question of whether the specific reading disorder of guessers may be linked to the same executive deficits which underlie ADHD. In order to unite a fast/inaccurate reading style with executive deficiencies, an attempt is made to incorporate the concept of executive control into models of lexical activation.

It is generally accepted that dyslexia is not a homogenous entity and that there are a number of subtypes of reading-disabled children (Benton, 1978; Rutter, 1978; Satz & Morris, 1981). Although the concept of subtypes is widely accepted, the manner in which subgroups are identified varies. For example, each of the studies listed by Hooper and Willis (1989, pp. 42–44) used different measures of achievement and cognition as the basis for group separation. In spite of this, we currently argue that the subtypes that have been distinguished by a number of dual-subtype models – e.g., Bakker's L and P type (1979, 1981); Van der Leij's *guessers* and *spellers* type (1983); Lovett's *accuracy* and *rate disabled* readers (1984), and Mitterer's *whole-word* and *recoding* subtypes (1982) – show some overlap and, in view of their reading style, seem to converge as two types of dyslexic children. The first type, referred to as *guessers*, manifests a fast and global reading style. This is characterized by errors such as omissions, additions, substitutions, letter reversals, false word identifications (misreading one word as another), and other word-mutilating errors. The second type, referred to as *spellers*, reads slowly and fragmentedly, since the identification of words is mainly based on an elaborate grapheme to phoneme translation process. The speller's reading style is accurate in that it leaves the ultimate reading response intact.

At the word recognition level, the slow/accurate-fast/inaccurate dichotomy has been associated with indirect- versus direct-word approach (Licht, 1989; Van Strien, Bouma, & Bakker, 1993). In the indirect or phonological route, word identification is attained through generation of a phonological representation, formed by the stepwise translation of graphemes into phonemes. The direct or lexical route does not require an intermediate phonological code, since the use of specific orthographic codes enables direct access to word memory. Licht (1989), Licht and Van Onna (1995), Van der Leij (1983), and Van Strien et al. (1993) argued that guessers and spellers may predominantly rely on the direct and indirect word recognition strategy, respectively.

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In the present study, dyslexic children have been classified as guessers and spellers on the basis of reading errors and reading speed according to criteria initially developed by Bakker (1981). The guesser-speller classification is based on a so-called *clinical-inferential* model for subtyping, and has been found to cover about 65% of the variability in the reading of dyslexics (Van Strien, Bakker, Bouma, & Koops, 1990; Van Strien, Bouma, & Bakker, 1993). Although *empirical* classification studies generally explain more variance in reading, they do so by extracting a larger number of subtypes. For example, by using multiple methods of cluster analysis, Morris et al. (1998) identified nine subtypes that represented 90% of their sample of 232 children. For a discussion of the clinical-inferential and empirical models, see Hooper and Willis (1989). However, the goal of the present study is not to explain as much variance in reading as possible, but to further differentiate fast/inaccurate and slow/accurate readers on a number of tasks that measure the efficiency and speed of the executive process of inhibition.

Clearly, the distinction between guessers and spellers differs from the classical distinction between phonological and surface dyslexics (e.g., Castles & Coltheart, 1993; Stanovich, Siegel, & Gottardo, 1997). Whereas the former distinction refers to differences in reading style (fast/direct *vs.* slow/indirect), the latter distinction refers to differences in deficits underlying word recognition problems (phonological *vs.* visuo-orthographical deficits). Yet, spellers may be equated with surface dyslexics in that they are presumed to have difficulties using visuo-orthographic cues for fast whole-word recognition (as a consequence of which they have to employ a spelling-like approach). Guessers, on the other hand, cannot be so easily equated with phonological dyslexics. Although guessers show a number of reading characteristics that are similar to the phonological dyslexia subtype, their fast, hasty reading style is not easy to explain.

Reading and Executive Function

The previous section suggests that differences between guessers and spellers may boil down to differences in the computational skills and speed of processing required for efficient word recognition. However, an alternative explanation has come from recent findings in the field of executive functioning (EF), which is thought responsible for the control of cognition and the regulation of behavior. There is a growing body of evidence that specific patterns of executive deficits exist in childhood psychopathological disorders such as ADHD, PDD/NOS, and autism (Pennington & Ozonoff, 1996). Children with ADHD appear to have inhibitory deficits that are revealed by "impulsive behaviors such as responding before a task is understood, answering before sufficient information is available, allowing attention to be captured by irrelevant stimuli (i.e., distractibility), or failing to correct obviously inappropriate responses" (Schachar & Logan, 1990).

The hasty and inaccurate reading characteristics of guessers seem to overlap with some of the criteria for ADHD, specifically impulsivity and distractibility. This raises the question whether guessers suffer from a mild form of ADHD. It is possible that impulsive behaviors go unnoticed in children who are primarily referred for poor reading performance. The purpose of the present study is to discover whether the differences in reading style and word recognition strategy between guessers and spellers are associated with differences in basic *executive* processes, in particular those concerning inhibitory control.

Association of Reading and Attentional Disorders

Our assumption that impulsivity and distractibility are associated with a guessing-like reading style is corroborated by a number of epidemiological studies. Estimates of coexisting RD in the ADHD population range between 9% (Halperin, Gittelman, Kline, & Ruddel, 1984) and 39% (August & Garfinkel, 1990) to 80% (McGee & Share, 1988), whereas the prevalence of ADHD in RD has been estimated to range from 26% to 41% (Holborow & Berry, 1986; Silver, 1981) to 50% (Lambert & Sandoval, 1980) (this overview is based on Shaywitz et al., 1995). Given the frequent co-occurrence of both disorders, a number of hypotheses have been put forward to explain the nature and etiology of this comorbidity.

One generally accepted view is that RD and ADHD share some common underlying factors (e.g., neurocognitive) which explain the comorbid symptoms. However, several investigators have argued that the co-occurrence of ADHD behaviors in children with RD does not reflect a "true" comorbid association (e.g., Pennington, Grossier, & Welsh, 1993), but may be attributed to separate sources of cognitive morbidity for ADHD and RD (August & Garfinkel, 1990; see also Ackerman, Dykman, & Gardner, 1990; Felton, Wood, Brown, Campbell, & Harter, 1987; O'Neill & Douglas, 1991). As a possible approach to disentangling the distinct versus shared sources of cognitive comorbidity, Cantwell and Baker (1991) suggested that studies need to take into account the possibility that there are subtypes of ADHD and RD. One of the goals of the present study was, therefore, to assess whether ADHD-like executive dysfunctions are associated more with the guesser than speller subtype in RD.

Dyslexia and Inhibition

As noted previously, the field of EF is a promising one for determining the underlying process deficit(s) of guessers and spellers. In a study by Kelly, Best, and Kirk (1989), it was indeed found that reading-disabled children have executive difficulties in, for example, selective and sustaining attention, inhibition of routine responses and set maintenance over and above specific reading deficits. Other studies have used the EF approach to address the question of comorbid RD and ADHD. Willcutt and Pennington (2000) found stronger associations between RD and the ADHD inattention subtype than between RD and the hyperactive-impulsive subtype. Purvis and Tannock (2000) assessed inhibitory performance in RD and ADHD employing a classical paradigm for inhibition: the stop signal task. They reported inhibitory deficits in both RD and ADHD. They concluded that inhibitory control does not differentiate RD from ADHD, but that phonological processing does. However, neither study specified the RD subtype.

Only two studies have examined the extent to which slow/accurate and fast/inaccurate subtypes of dyslexia are differentially capable of inhibiting irrelevant responses (De Sonneville, Neijens, & Licht, 1993; Licht, 1989). It appeared that guessers have greater difficulty than spellers in inhibiting an experimentally induced response bias when performing a sustained attention task (De Sonneville et al., 1993). In addition, guessers were more susceptible to interference in the Stroop Color-Word Test than spellers (Licht, 1989).

These findings and the hasty and impulsive reading behaviors of guessers suggest that these children may have an inhibitory deficit in addition to or underlying their reading problem. Although guessers typically are not diagnosed as ADHD (their primary problems present as RD), this does not exclude the possibility that their reading disorder is associated, at least in part, with the same executive deficits found in ADHD.

Research Objectives

The goal of the present investigation is to establish a distinct pattern of deficient EF skills that would distinguish the guessing type of dyslexia from the spelling type. For this purpose, guessers were compared with spellers on the following executive functions: response inhibition, as determined by the stop signal task (Logan & Cowan, 1984); susceptibility to interference from irrelevant information, as determined by the Stroop task (Stroop, 1935); and planning, as determined by the Tower of London (TOL; Shallice, 1982). These measures of impulse control were chosen as ADHD children perform more poorly than controls on these tasks. In addition, the Abbreviated Conners Teacher Rating Scale (ACTRS) was used to assess "daily-life" symptoms of inattention, impulsivity, and hyperactivity (Goyette, Conners, & Ulrich, 1978).

It was hypothesized that only guessers would show a pattern of EF deficits similar to that reported for ADHD children and that spellers would not.

METHOD

Subjects

Subjects were children of 9–12 years who were recruited from two special schools for learning-disabled children and from one normal primary school. Learning-disabled children whose reading disturbance could be attributed to emotional problems, sociocultural factors, or gross neurological deficits on the basis of school records were not included in the sample. All children who participated ($N = 80$ for reading disabled and $N = 20$ for controls) were healthy and had normal or corrected-to-normal vision, and their IQ scores (obtained from school records) were in the normal range (IQ > 85). None of the children was diagnosed as ADHD using DSM-IV criteria (American Psychiatric Association, 1994), nor did they participate (or had been participating) in ADHD treatment programs.

Assessment of Dyslexia

To assess current reading levels, all children were administered a standard Dutch word-reading test, the Two-Minutes Test (TMT; Brus & Voeten, 1973), which consists of lists of words that become progressively more difficult. The TMT score (the number of words read correctly in two minutes) was converted into a reading-age equivalent (RAE; Struiksma, Van der Leij, & Vieijra, 1989) reflecting the child's *actual* reading level expressed in the number of months of reading instruction (one year of instruction being equivalent to 10 months). The *expected* reading-age (ERA) is equivalent to the number of months that a child has actually received formal reading instruction. The Netherlands employs a very systematic method of reading instruction, so the ERA-RAE difference enabled us to assess any lag in reading performance almost down to one month. Children who lagged 15 months or more in reading (ERA-RAE) were considered to be dyslexic ($N = 75$; five learning-disabled children did not fulfill this criterion and were removed from the sample). Consequently, only those children were admitted to the subsequent guesser-speller classification procedure.

It should be emphasized that the ERA-RAE procedure goes beyond a simplistic chronological age-grade level discrepancy formula in that the number of months of actual reading instruction, and not chronological age, is used to define reading lag. In addition, the educational age-norms for average reading level were obtained in extensive standardization studies on reading in the Dutch population of primary-school children.

All of the control children ($N = 20$) came from the normal primary school and their RAEs approximated their ERAs.

Classification of Guessers and Spellers

Subsequent to the TMT, the dyslexic children were given a standardized Dutch sentence-reading test (AVI; Van den Berg & Te Lintelo, 1977). This test consists of nine texts of increasing difficulty. The number of texts actually mastered (i.e., read within time and error limits) determines the child's level of text reading.

The AVI was employed to classify the dyslexics as spellers or guessers on the basis of reading speed, the number of substantive errors (SE; e.g., omissions, additions, substitutions, letter reversals) and the number of time-consuming errors (TE; e.g., hesitations, stammerings, fragmentations, repetitions, corrections). In order to evoke a sufficient number of errors on which to base the speller (relatively many time-consuming errors) – guesser (relatively many substantive errors) classification, a text two levels above the child's mastery level was presented and assessed on reading speed and reading errors.

Reading speed (RS) was expressed as the total reading time divided by the time norm for the text * 100, whereas reading error (RE) was expressed as the proportion of TE errors relative to the total number of errors (SE + TE). A child was classified as having the guessing type of dyslexia when RS < 115 and RE < .40 (more than 60% of errors made were substantive errors), and as having the spelling type of dyslexia when RS > 135 and RE> .60 (more than 60% of errors made were time-consuming errors). The classification criteria were similar to those used by Van Strien (1999) and Patel and Licht (in press) and were adapted from Bakker and Vinke (1985) and Van Strien, Bakker, Bouma, and Koops (1990). Using this classification system, we were able to classify about 60% of our dyslexics as either spellers or guessers ($N = 45$). The final groups of guessers ($N = 20$) and spellers ($N = 20$) were formed by selecting those children who showed most clearly the characteristics of each type.

Symptoms of ADHD in Dyslexics

In order to evaluate possible comorbid ADHD-like symptoms in our sample of dyslexics, teachers of the dyslexic children and controls rated the children with the ACTRS (Goyette, Conners, & Ulrich, 1978). A one-way analysis of variance performed on the rating scores revealed a significant group effect: $F(2,56) = 9.51$, $p < .001$, eta = .254 (for one control child, a rating was not available).

As expected, guessers displayed higher scores than controls ($p < .001$) and spellers ($p < .08$). Group characteristics are presented in Table 1.

Tasks and Procedure

Four tasks were administered: (1) a Word Decoding Task; (2) the Stroop Color-Word task; (3) the Tower of London task; and (4) a stop signal task. Tasks 1, 2 and 3 were presented to guessers and spellers only, since the primary interest here was how these tasks might differentiate between guessers and spellers. Task 4 was also administered to normal readers.

The Word Decoding Task (WDT)

The WDT (Van Aarle & Volleberg, 1986) required the child to read aloud a random list of 30 phonological regular words, 30 irregular words (IW), and 30 pseudo words (PW). Each word was centrally presented on a computer screen (black-on-white) for 5 s. The WDT was included to test the working hypothesis that spellers have difficulty using visuo-orthographical cues for fast whole-word recognition, and that guessers have problems with phonological processing. Spellers are expected to make more errors on irregular words (that call upon the direct route for identification), and guessers are expected to make more errors on pseudo words (that call upon the indirect route for identification). As the number of errors in reading regular words is not a critical factor with regard to the present hypothesis, we decided to restrict the analyses to pseudo words and irregular words.

The Stroop Color-Word task (STROOP)

The STROOP, adapted for use with Dutch-speaking children by Hammes (1978), was administered.

The Tower of London task (TOL)

In the TOL, subjects had to move a pattern of beads from a start configuration to a goal configuration as efficiently as possible. The task requires the forward planning of sequences of actions in order to solve a particular problem. The level of problem difficulty progressed through the test by increasing the minimum number of moves required for a solution. In total, the subject was asked to solve 12 problems. Here, TOL performance is reflected only by the minimum number of moves necessary to solve *all* problems ($n = 46$) minus the total number of additional (i.e., incorrect) moves. The higher the score, the higher the problem-solving capability.

The stop signal task (STOP)

The stop task is a choice reaction time task that requires the subjects to respond to a visual stimulus and to inhibit their response on the infrequent presentation of an auditory stop signal (Logan & Cowan, 1984; Logan, Cowan, & Davis, 1984).

Each trial began with the presentation of a square warning stimulus (1.40 cm * 1.40 cm) for a duration of 500 ms. This was followed by the primary task stimulus, which was displayed for 125 ms. After the imperative signal was extinguished, the screen was blank for 2,375 ms. The stimuli for the primary task were the uppercase letters X, A, O, and P. Each letter was 1.80 cm wide and 2.90 cm high. Both the warning stimuli and the stimulus letters were presented in black-on-white at the center of the screen. The primary choice reaction time task was simple: a capital X or A required a response with one hand, a capital O or P required a response with the other. Mapping of letters onto response hands was counterbalanced across subjects.

The stop signal was a 1,000 Hz tone, with an intensity of 65 dB(A) and a duration of 350 ms. It was presented binaurally on 25% of the trials, occurring an equal number of times at each of six stop signal delays as with an X, A, O, and P. The sequence of primary task stimuli, stop signals, and stop signal delays was pseudo-randomized.

A practice block was presented first, followed by nine test blocks of 48 trials yielding 18 stop signals in each stop signal delay. The test blocks were arranged in groups of three, in between which the subjects took a short break.

Stop signal delays were set relative to the child's mean primary task reaction time (MRT): MRT-500, MRT-400, MRT-300, MRT-200, MRT-100, and MRT-0 ms. To correct for differences between subjects in MRT and strategy (e.g., a subject may delay his/her response in an attempt to enhance the probability of inhibiting), stop signal delays in block n were set relative to the MRT in block $n\text{-}1$ (block-to-block tracking). In the first block, stop signal delays were set relative to the MRT in the practice block.

Subjects were instructed to respond as quickly and as accurately as possible to the primary task stimuli and to withhold their response whenever a stop signal occurred. It was explained that stop signal delays were variable and that stop signals could be presented so late that it would be difficult to suppress the primary response. Finally, subjects were explicitly instructed not to delay their responses to the primary task in order to improve stopping.

For each child, the following primary task measures were derived from the go-trials: mean reaction time (MRT), standard deviation (SD), percent-

Table 1. Characteristics for Each Reading Group.

	Boys	Girls	Age		Reading Age[a]						Reading Speed[b] (on AVI)		Error Type[c] (on AVI)		Conners Rating Scale	
					Expected		Actual		Difference							
Spellers	13	7	10.5	(1.0)	41.7	(11.4)	21.1	(10.1)	20.6	(5.0)	153.9	(29.8)	.67	(.14)	6.5	(6.8)
Guessers	14	6	10.6	(1.0)	40.4	(10.2)	18.2	(6.6)	22.2	(6.9)	84.7	(21.4)	.30	(.12)	10.8	(8.0)
Controls	12	8	10.9	(0.4)	40.0	(5.6)	42.1	(7.1)	–2.1	(9.3)	–		–		2.1	(2.1)

Note. Numbers in parentheses are standard deviations.
[a] Reading age is in months; 10 months equals 1 year of reading instruction.
(The Actual Reading Age is derived from the Two-Minutes-Test (TMT) (Brus & Voeten, 1973)).
[b] Reading speed is expressed as 100 * (time needed / time norm).
[c] Error type is expressed as *N*(time-consuming errors) / *N*(substantive + time-consuming errors).

age of errors (pressing with the X/A-finger when an O or P was presented or vice versa) and percentage of omissions (non-responses).

Inhibition functions were generated by computing the proportion of stop signal trials, at each stop signal delay, on which subjects successfully inhibited their primary response. Effects of subject group (guessers, spellers, and normal readers) on the probability of inhibition were examined in repeated measures analyses of variance (ANOVA) with groups a as between-subject factor and delay as a within subjects factor. Follow-up tests were carried out when necessary. To analyze the differences in the shape of the inhibition function in a more accurate way, ANOVAs were performed on the slopes of the regression lines that were fitted to the inhibition functions when plotted as a function of a *Z*-score that represents the Relative Finishing Time (ZRFT) of the stop and go processes in standard deviation units of the primary task RTs (see Logan, Cowan, & Davis, 1984). When inhibition functions from different groups cannot be aligned by plotting them against ZRFT, it may be concluded that a lower and flatter function represents a ‘‘deficiency’’ in the executive process of inhibition.

To explore more specific deficits in the stopping process, mean stop signal reaction times (SSRTs) were estimated for each individual, taking into account the probability of response at each stop signal delay and the distribution of primary task reaction times (for the estimation procedure, see Logan, Cowan, & Davis, 1984). Analyses of variance and subsequent post-hoc tests (to locate between-group differences) were conducted to examine the effects of reading group on both SSRT and ZRFT slope.

Apparatus

Stimuli were presented with a 386SX-25 PC, with timing control from a master computer, a 486DX2-66 PC. The master computer recorded the manual responses. The stimuli were presented on a NEC Multisync 5FG monitor positioned at 70.00 cm from the subject's eyes.

RESULTS

WDT

As shown in Figure 1, more errors were made in reading irregular words than in reading pseudo words ($F(1,38) = 8.24$, $p < .01$, eta = .178, pooled across reading group). The effect of word category was substantially larger for spellers (average increase of 4.7 errors) than for guessers (average increase of 0.8 errors), as was evident by the interaction between reading group and word category ($F(1,38) = 4.33$, $p < .05$, eta = .102). An Independent-Samples *t* test revealed that spellers tended to make more errors in reading irregular words than guessers ($t(38) = 1.78$, $p < .08$).

STROOP

Figure 2 (left panel) shows that guessers needed 74 additional seconds to complete the ‘‘color naming of words’’ condition relative to the ‘‘color naming of blocks’’ condition. Spellers required 66 extra seconds. The between-group difference was not significant ($t(34) = .76$; the Stroop test could not be obtained from two guessers and two spellers).

The right panel of Figure 2 displays the interference effect on the number of errors for both reading groups. An analysis of variance revealed a significant interaction between group and condition ($F(1,34) = 4.62$, $p < .05$). The interference effect was more pronounced for guessers (average increase of 5.9 errors) than for spellers (average increase of 3.2 errors) ($t(34) = 2.2$, $p <$

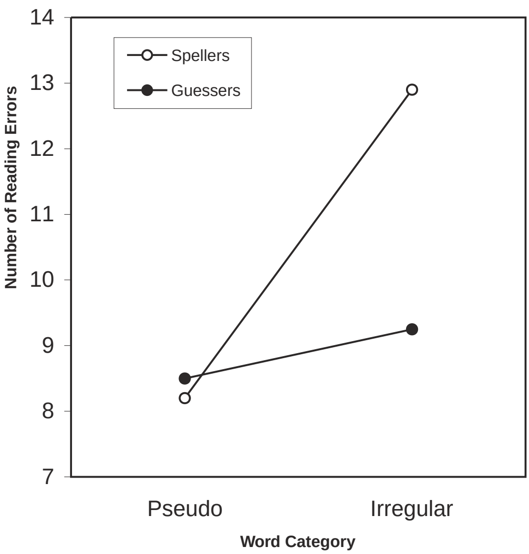

Fig. 1. The Interaction Effects Between Word Category (Pseudo vs. Irregular) and Reading Group.

.05). Apparently, guessers were more susceptible to interference due to the automatic generation of written word meaning when naming the color.

TOL

A between-subject *t* test showed that the mean TOL score of guessers (28.4) was significantly lower than that of spellers (33.6) ($t(38) = 2.64$, $p < .05$), indicating that fast/inaccurate readers made more incorrect moves than slow/accurate readers.

The Stop Signal Task

One-way analyses of variance were conducted separately for MRT to go-trials in the primary task, the standard deviation (SD) of MRT, the percentage of errors, and the percentage of omissions of the primary task. Means and standard deviations of each of these dependent measures in each subject group (controls, spellers, and guessers) are provided in Table 2.

Significant group effects were obtained for MRT ($F(2,57) = 6.69$, $p < .005$, eta = .190), standard deviation of MRT ($F(2,57) = 10.40$, $p < .001$, eta = .267), and percentage errors ($F(2,57) = 5.12$, $p < .01$, eta = .152). Subsequent post-hoc tests (Tukey's HSD) revealed that the MRT was significantly slower in the dyslexia subgroups compared to the control group ($p < .005$ and $p < .05$ for spellers and guessers, respectively). In addition, spellers ($p < .001$) and guessers ($p < .001$) showed a greater amount of primary task variability than normal readers. Finally, dyslexics made the most hand errors, as was evident in a significant guesser-control ($p < .05$) and a marginally significant speller-control ($p < .06$) difference. The rate of omission errors did not differ among groups.

Figure 3 displays the probabilities of inhibition as a function of MRT delay and as a function of Z-relative finishing times (ZRFT).

An analysis of variance with one between-subject factor (i.e., Group; three levels) and one repeated factor across Delay (six levels) was conducted for the probability of inhibition (P(Inhibit)). The effect of Group on the mean P(Inhibit) (over all delays) was marginally significant ($F(2,57) = 2.62$, $p < .08$, eta = .084), signifying slight differences in the height of the inhibition function. As predicted by the race model, P(Inhibit) was strongly affected by De-

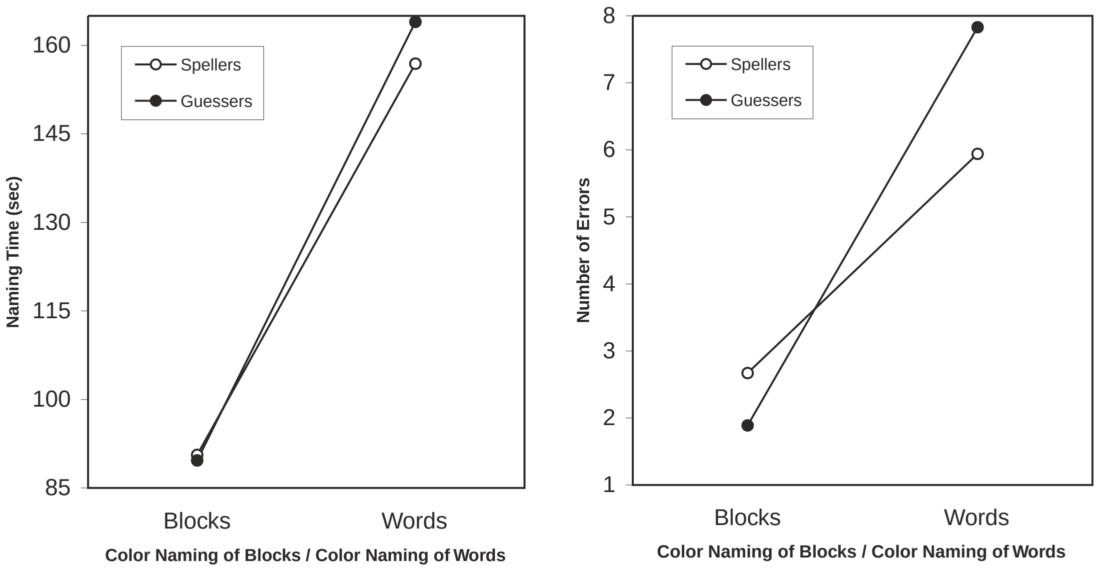

Fig. 2. The Stroop Interference Effect on Naming Time (Left Panel) and Number of Errors (Right Panel) for Each Reading Group.

Table 2. Performance on the Stop Signal Paradigm as Reflected by the Means and Standard Deviations for the Dependent Measures for Each Reading Group.

Measure	Reading Group					
	Spellers		Guessers		Controls	
	M	(*SD*)	*M*	(*SD*)	*M*	(*SD*)
MRT (go-task)	795.70	(121.21)	758.62	(109.52)	676.73	(81.00)
SD of MRT	287.87	(80.71)	290.22	(94.62)	190.82	(55.63)
% of errors	6.92	(5.55)	8.00	(5.65)	3.09	(3.92)
% of omissions	3.78	(3.15)	3.43	(2.47)	2.36	(2.25)
slope (ZRFT)	26.95	(14.52)	19.29	(9.52)	16.42	(8.42)
SSRT	225.07	(88.21)	301.40	(138.65)	256.93	(78.19)

Note. M = mean; SD = standard deviation; MRT = Mean Reaction Time; SSRT = Stop Signal Reaction Time; ZRFT = Z-score Relative Finishing Time; all times are in ms.

lay ($F(5,285) = 111.23$, $p < .001$, eta = .661). The groups were affected similarly; that is, the interaction between Group and Delay did not reach conventional levels of significance ($F(10,285) = 1.56$, $p = .12$, eta = .052).

Subsequent post-hoc comparisons (simple effects; Winer, 1971) indicated that the inhibition functions for guessers were significantly lower ($p < .05$) than those observed for spellers. In addition, they tended to be flatter ($p < .08$).

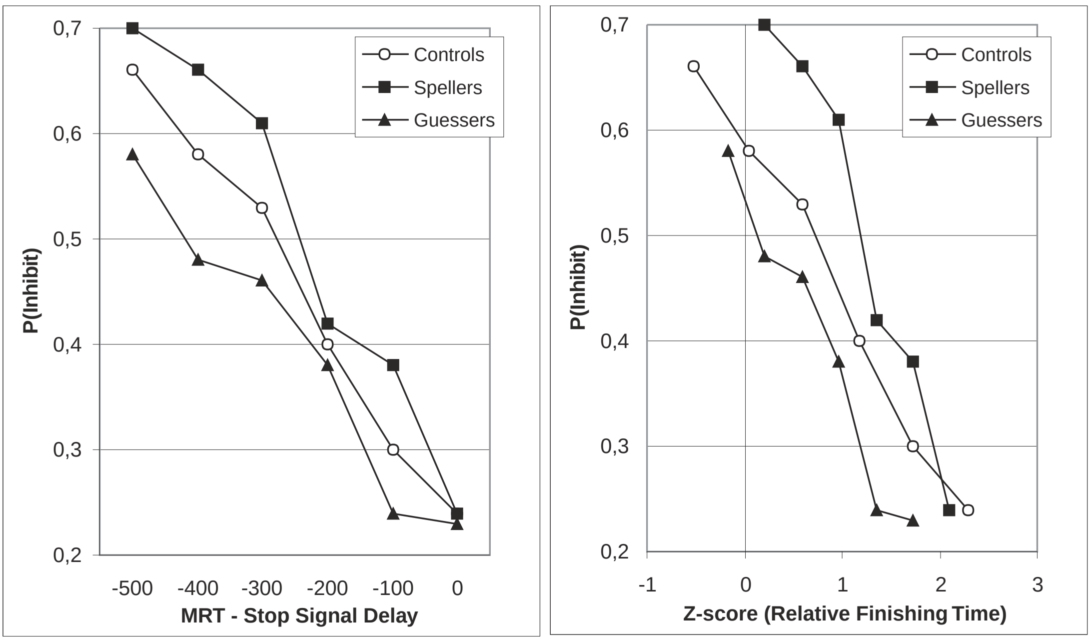

Fig. 3. The Probability of Inhibition as a Function of MRT Delay (Left Panel) and ZRFT (Right Panel) for Each Reading Group.
Note. MRT = Mean Reaction Time; ZRFT = Z Score Relative Finishing Time.

To examine the linear component of the Group * Delay interaction more precisely, a one-way analysis of variance was carried out on the slope of the ZRFT regression lines. This analysis revealed a significant group effect ($F(2,57) = 4.78$, $p < .05$, eta = .143), suggesting that variation in stop signal delay differentially affected the rise of the inhibition functions. Post-hoc tests (Tukey's HSD) revealed that the ZRFT slopes of spellers were significantly steeper than those of guessers ($p < .05$) and controls ($p < .05$). The observed differences in the efficiency of the executive inhibition process were confirmed by a one-way analysis of variance conducted for the estimated stop signal reaction times (SSRTs), demonstrating a significant group effect ($F(2,57) = 3.43$, $p < .05$, eta = .108). Post-hoc tests demonstrated that the stopping process in guessers was significantly slower than in spellers ($p < .05$). Mean values and standard deviations of SSRT and ZRFT slope are presented for each group in Table 2.

Teacher Ratings of Impulsivity and Reading Performance

Finally, we examined the relationship between teacher ratings of impulsivity and reading performance on the TMT. The TMT was firstly employed to assess reading lag, and required the children to read lists of words for two minutes. Although guessers and spellers read about the same number of words correctly, both reading groups differed in the way this composite score was constructed. As would be expected, guessers read faster but more inaccurately than spellers. That is, they read more words in total (10, on average) but made more errors (12, on average). Interestingly, a regression analysis revealed that, in guessers, there was a significant relationship between teacher ratings of impulsivity and reading speed ($F(1,18) = 8.05$, $p < .05$), with ratings of impulsivity accounting for 31% of the variance in the total number of words read within two minutes. Additionally, guessers demonstrated a significant relationship between teacher ratings of impulsivity and reading accuracy ($F(1,18) = 9.54$, $p < .01$), with ratings of impulsivity accounting for 35% of the variance in the number of reading errors made within two minutes. Spellers, on the other hand, neither exhibited a significant relationship between teacher ratings of impulsivity and reading speed ($F(1,18) = 1.01$, R Square = 5%) nor a significant relationship between teacher ratings of impulsivity and reading accuracy ($F(1,18) = 1.16$, R Square = 6%).

DISCUSSION

In this study, dyslexic children classified as guessers were compared with children who showed a spelling type of dyslexia on three aspects of executive functioning: response inhibition, susceptibility to interference from irrelevant information, and planning. Using our classification system, guessers and spellers were found to cover about 60% of the variability among the dyslexics. Obviously, more variability would have been explained if more subtypes were included, or if an empirical model for subtyping was employed (see Morris et al., 1998). It should be emphasized, however, that the goal of the present study was not to explain as much variance in reading as possible but to differentiate between guessers and spellers on a number of EF tasks. The discussion of the results focuses on the guesser-speller distinction when it concerns executive deficits and association with ADHD symptoms. In order to unite a fast/inaccurate reading style with executive deficiencies, an attempt is made to incorporate the concept of executive control into models of word recognition and lexical activation.

Clearly, the predicted guesser-speller differences were evident from the performance observed in the stop task. In comparison with spellers, guessers were found to have a slower inhibitory process (SSRT) and a lower and flatter inhibition function. Since block-to-block tracking allowed for the assessment of inhibitory control independently of primary response speed, and since the inhibition function slopes were obtained after the application of the ZRFT normalization procedure, the differences in inhibition functions cannot be explained by group differences in MRT, SSRT, and $SD_{(MRT)}$. These results show that guessers are impaired in their ability to inhibit inappropriate responding.

The specific mechanisms underlying the inhibitory deficits in guessers are as yet unclear. Logan and Cowan (1984) suggest that a high variability in the speed of the stop process and a low triggering probability, in addition to reduced speed of stopping, contribute to inhibitory deficits. All of these mechanisms result in a lower and flatter inhibition function.

Do Guessers Suffer from a General Executive Deficit?

Although the above explanation of inhibitory deficits in guessers focuses specifically on stopping mechanisms, it is possible that poor response inhibition may also be part of a more general impairment in executive functions, which in turn may be attributable to a frontal lobe dysfunction. Such explanations for response inhibition deficits have been based on studies that aimed at uncovering the mechanisms that underlie the impulsive behaviors of ADHD children (Barkley, 1994, 1997; Barkley, Grodzinsky, & DuPaul, 1992; Grodzinsky & Diamond, 1992; Pennington & Ozonoff, 1996; Shue & Douglas, 1992). It appeared that these children, but also children with other developmental psychopathologies, displayed abnormalities in response inhibition on a variety of executive tasks (i.e., tasks that substantially call upon functions mediated by the (pre)frontal lobes). Evidence in support of the hypothesis that guessers may have similar executive deficits is provided by the Stroop task and the Tower of London task.

On the TOL, guessers made more incorrect (i.e., impulsive) moves than spellers. Apparently, the type of anticipatory planning capabilities required in this kind of problem-solving task are not fully developed in guessers, or they are disrupted by impulsive responses. In addition, guessers were less able to inhibit the interference of an irrelevant word (e.g., blue) on naming the color of the ink (e.g., red) in the Stroop task, as evidenced by their larger number of errors. The Stroop effect is considered to be a good example of automatic, uncontrolled word reading and the ability to control/inhibit reading when necessary (Rafal & Henik, 1994).

In the present experiment, the impaired ability of guessers to control reading was not only manifest in the Stroop Color-Word test, but also in the AVI text-reading test and TMT word-reading test, in which they read too fast and inaccurately. In the trade-off between speed and accuracy, guessers seem to give priority to the former dimension of reading performance and neglect the latter. Such an explanation of the poor reading performance of guessers is no longer primarily linked to an underlying disorder of language (Shaywitz, Fletcher, & Shaywitz, 1994) but rather refers to more general deficits in information processing style or strategy.

It is interesting to note that a fast but inaccurate response strategy has also been established in ADHD children using tests that measure impulse control, such as MFFT (Barkley, 1991; DuPaul, Anastopoulos, Shelton, Guevremont, & Metevia, 1992; Milich & Kramer, 1984; Sergeant, Van Velthoven, & Virginia, 1979). The overlap between response styles of guessers and ADHD children raises the question whether the guessing type of dyslexia and disorders of attention and activity may share a common pathway.

Since the present study lacks a group of children with ADHD as well as a comorbid RD+ADHD group, the issue of (the nature of) the comorbidity of RD and ADHD cannot be addressed directly. Nonetheless, the poor performance of guessers on the EF tasks suggests that at least a parallel may be drawn between guessers and ADHD children, as the latter group is believed to suffer from the same type of deficits in executive functioning (see Barkley et al., 1992; Pennington & Ozonoff, 1996; Pennington et al., 1993). Yet, ADHD children and guessers seem to differ in the manner of expressing these deficits. In ADHD children, executive deficits result in a broad range of inattentive, hyperactive, and impulsive behaviors, whereas, in guessers, the symptoms of poor impulse control seem particularly to be manifested in their reading style. It is probable that their symptoms are not sufficiently present to meet the DSM-IV criteria for ADHD, since none of the participating guessers was classified as ADHD.

However, when the classroom teachers were asked to rate the children on the ACTRS (Goyette, Conners, & Ulrich, 1978), guessers were found to display higher scores than spellers and normal readers. This finding suggests that there is a link between impulsive responding in the classroom and impulsive responding in a reading task. Secondly, it demonstrates that guessers behave like ADHD children not only on the laboratory-based measures of impulse control but they also resemble them in a more natural classroom setting.

Further support for our notion that guessers share executive deficits with ADHD comes from distinct patterns of correlations between teacher ratings on the Conners scale and inhibitory efficacy on the Stroop task (errors) and on the stop task (ZRFT slope) found for guessers. Within the group of guessers, the rating scores correlated highly with Stroop task performance (r = .54, $p < .05$) and moderately with stop task performance ($r = -.33$, $.05 < p < .10$). Furthermore, Stroop interference correlated moderately with ZRFT slope ($r = -.34$, $.05 < p < .10$). In spellers, the correlations were found to be low (and, in the case of the ZRFT slope, in the opposite direction) (r = .19, r = .24, and $r = -.02$, respectively). Apparently, there is a link between teacher ratings of impulsivity, Stroop interference, and ZRFT slope only in guessers. The observed pattern of association may be explained by postulating a common underlying deficit in executive functions that equally affects the different measures of impulse control.

In sum, the conclusion drawn by Purvis & Tannock (2000) that inhibitory control does *not* differentiate RD and ADHD may be premature, in that its validity would seem to depend on RD subtype. The present data suggest that this conclusion may only apply to guessers but not spellers.

Is There a Link Between the Guessers' Executive Deficits and Their Reading Disturbance?

The present study shows that guessers are impaired in their ability to inhibit inappropriate responding and that this disability might reflect EF deficits. The crucial question that needs to be addressed is whether these executive deficits may also underlie the guessers' impulsive *reading* behaviors or whether a language-based disorder has to be assumed. Since the EF tasks did not tap critical elements of reading, no direct (i.e., causal) relationship between executive dysfunctions and specific reading disturbances can be deduced from the present experiment. However, the finding that guessers performed more poorly than spellers on the stop task, the Stroop task, and the TOL task, as well as the finding that guessers displayed higher rating scores on the ACTRS, suggests that there is at least some degree of association between them. More direct support for this line of reasoning comes from the observation that there is a close relationship between teacher ratings of impulsivity and speed and accuracy of reading only in the guessers. This result suggests that guessers have a deficit in EF that is apparent both cognitively and behaviorally. It remains to be seen whether the above relationship can be replicated in a group of children whose symptoms of impulsivity, hyperactivity, and inattention pass the DSM-IV threshold for ADHD.

In the introduction of this paper, it was cautiously suggested that guessers may have problems with phonological processing similar to those observed in the phonological dyslexia subtype described by Castles & Coltheart (1993) and Stanovich et al. (1997). However, the results of the WDT conflict with this notion, since guessers did not make more errors on pseudo words than on irregular words. Clearly, this reinforces our argument that we need to focus on an inhibitory explanation for the guessers' reading disturbance. Below, it is speculated how the concept of executive control may be incorporated into models of lexical activation (Morton, 1979; Morton & Patterson, 1980; Treisman, 1960).

According to activation models, orthographic information about a target word accumulates gradually in the visual system, and, as it accumulates, intermediary candidate words are concurrently primed or activated in the lexicon. The basic mechanism of word recognition is then to raise the activation level of one of the candidate words (i.e., the target word) above some critical threshold value. We argue that this theoretical framework may account (at least to some extent) for the guessing type of dyslexia, if one assumes that guessers have lower word thresholds than normal readers. Another possibility is that guessers may have more difficulty with "dampening" the activation of candidates that are likely to be false. Both assumptions predict that, in guessers, false candidate words have an increased chance of being prematurely identified as the target word. In a reading (aloud) task, this would be evidenced by an impulsive style of reading that is characterized by a high prevalence of substantive errors. As noted earlier, several classification studies have discovered a (guessing) subtype of dyslexia that displays such a distinct profile of reading performance (Bakker, 1979, 1981; Lovett, 1984; Mitterer, 1982; Van der Leij, 1983).

It should be stressed that the above explanation of the guessers' impulsive reading style is highly speculative and that, evidently, more research is needed to empirically establish whether and, if so, in what way a lack of executive control affects the processes involved in word recognition. In word *comprehension*, however, the role of a *general cognitive* mechanism of suppression has been investigated by Gernsbacher and Faust (1991). According to Gernsbacher's (1990) structure-building framework, a presented word activates a number of potential meanings. The role of the suppression mechanism is then to dampen the activation of the less likely meanings (so that the appropriate meaning can be more easily accessed). Interestingly, Gernsbacher and Faust concluded that a less efficient suppression mechanism underlies deficient general comprehension skills. This reinforces our idea that a suppression mechanism may (also) play a role in word recognition.

The Deficit(s) Underlying the Reading Problems in Spellers

The reading of spellers is characterized by the stepwise conversion of the words' graphemic segments into phonemes. These phonemes are then blended to form a word. This style of reading was manifest in the spellers' performances on the AVI sentence-reading test, the TMT word-reading test and the WDT. In the AVI and TMT, their reading was slow, elaborate, and marked by many time-consuming errors. In the WDT, they displayed the expected problems with irregular words that are mispronounced when merely deciphered phonologically. What type of deficit may underlie these difficulties with reading? As previously argued, one explanation is that spellers have difficulties using visuo-orthographic cues for fast whole-word recognition, as a consequence of which they have to fall back on the phonological route of word identification. In this context, our spellers may be equated with the surface dyslexics as identified by Castles & Coltheart (1993) and Stanovich et al. (1997).

Here, spellers proved to be highly capable of inhibiting inappropriate responding on the stop task, the Stroop task, and the TOL task. On the stop task, they even displayed steeper ZRFT slopes than controls. Although this finding is intriguing, it is not easy to interpret. One possible explanation is that, due to the relatively small sample sizes (n = 20), there may have been insufficient power to align the inhibition functions of spellers and controls. Another explanation is that the observed superior inhibition of spellers is an artifact of our selection procedure. Spellers were selected on the basis of slow but accurate reading on the AVI text-reading test. It is possible that the slow/accurate-fast/inaccurate dimension of reading performance overlaps with some inhibitory dimension that corresponds with high and poor inhibitory skills in a stop task situation, respectively. The main difference between guessers and spellers concerns the nature of the association between both types of dimensions. In guessers, the hypothesized executive deficits probably lead to both poor behavioral and cognitive inhibition, whereas spellers show superior behavioral inhibition, which may be a burden to them when speeding up reading.

Interestingly, Quay (1988a, 1988b), Oosterlaan and Sergeant (1998), Pliszka, Borcherding, Spratley, Leon and Irick (1997), and Oosterlaan (2000) found that children with anxiety disorders show more efficient response inhibition than controls. These authors suggested an *over-*

active inhibition system underlying the anxiety problems in these children. A similar mechanism may also underlie the superior inhibitory performance of spellers on the stop task.

The suggestion that spellers may have an overactive inhibition system raises the question whether the slow and fragmented style of reading of spellers can also be ascribed to this system. If we follow the same line of reasoning used to explain the fast/inaccurate reading style of guessers, we have to assume that an overactive inhibition system slows down the mechanism of word recognition. In terms of lexical activation, it may do so because spellers have critical word thresholds that are too high, as a result of which they waste too much time raising the activation level of a target word above threshold and ensure recognition. Or, it can be speculated that spellers have problems with ''enhancing'' the activation of the most likely candidate words. Future research will be needed to examine these explanations.

REFERENCES

Ackerman, P.T., Dykman, R.A., & Gardner, M.Y. (1990). ADD students with and without dyslexia differ in sensitivity to rhyme and alliteration. *Journal of Learning Disabilities, 23*, 279–283.

American Psychiatric Association (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: American Psychiatric Association.

August, G.J., & Garfinkel, B.D. (1990). Comorbidity of ADHD and reading disability among clinic-referred children. *Journal of Abnormal Child Psychology, 18*, 29–45.

Bakker, D.J. (1979). Hemispheric differences and reading strategies: Two dyslexias? *Bulletin of the Orton Society, 29*, 84–100.

Bakker, D.J. (1981). A set of brains for learning to read. In K.C. Diller (Ed.), *Individual differences and universals in language learning aptitude* (pp. 56–71). Rowley: Newbury House.

Bakker, D.J., & Vinke, J. (1985). Effects of hemisphere-specific stimulation on brain activity and reading in dyslexics. *Journal of Clinical and Experimental Neuropsychology, 7*, 505–525.

Barkley, R.A. (1991). The ecological validity of laboratory and analogue assessment methods of ADHD symptoms. *Journal of Abnormal Child Psychology, 19*, 149–178.

Barkley, R.A. (1994). Impaired delayed responding: A unified theory of attention deficit disorder. In D.K. Routh (Ed.), *Disruptive behaviour disorders in childhood* (pp. 11–57). New York: Plenum Press.

Barkley, R.A. (1997). Behavioral inhibition, sustained attention, and executive functions: Constructing a unifying theory of ADHD. *Psychological Bulletin, 121*, 65–94.

Barkley, R.A., Grodzinsky, G., & DuPaul, G. (1992). Frontal lobe functions in attention deficit disorder with and without hyperactivity: A review and research report. *Journal of Abnormal Child Psychology, 20*, 163–188.

Benton, A.L. (1978). Some conclusions about dyslexia. In A.L. Benton & D. Pearl (Eds.), *Dyslexia: An appraisal of current knowledge* (pp. 451–476). New York/London: Oxford University Press.

Brus, B.T., & Voeten, M.J.M. (1973). *Een-minuuttest, vorm A en B, verantwoording en handleiding.* Nijmegen: Berkhout.

Cantwell, D.P., & Baker, L. (1991). Association between attention deficit-hyperactivity disorder and learning disorders. *Journal of Learning Disabilities, 24*, 88–95.

Castles, A., & Coltheart, M. (1993). Varieties of developmental dyslexia. *Cognition, 47*, 149–180.

De Sonneville, L.M.J., Neijens, L., & Licht, R. (1993). Leer- en aandachtstoornissen: vroegtijdige onderkenning en samenhang. In E.J.M. Van Aarle & K. Hennemans (Eds.), *Dyslexie 1992, verslag van het IDA congres.* Lisse: Swets & Zeitlinger.

DuPaul, G.J., Anastopoulos, A.D., Shelton, T.L., Guevremont, D.C., & Metevia, L. (1992). Multimethod assessment of attention deficit hyperactivity disorder: The diagnostic utility of clinic-based tests. *Journal of Clinical Child Psychology, 21*, 394–402.

Felton, R.H., Wood, F.B., Brown, I.S., Campbell, S.K., & Harter, M.R. (1987). Separate verbal memory and naming deficits in attention deficit disorder and reading disability. *Brain and Language, 31*, 171–184.

Gernsbacher, M.A. (1990). *Language comprehension as structure building.* Hillsdale, NJ: Erlbaum.

Gernsbacher, M.A., & Faust, M.E. (1991). The mechanism of suppression: A component of general comprehension skill. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17*, 245–262.

Goyette, C.H., Conners, C.K., & Ulrich, R.F. (1978). Normative data on revised Conners parent and teacher rating scales. *Journal of Abnormal Child Psychology, 6*, 221–236.

Grodzinsky, G.M., & Diamond, R. (1992). Frontal lobe functioning in boys with attention-deficit hyperactivity disorder. *Developmental Neuropsychology, 8*, 427–445.

Halperin, J.M., Gittelman, R., Klein, D.F., & Ruddel, R.G. (1984). Reading disabled hyperactive children: A distinct subgroup of attention deficit disorder with hyperactivity? *Journal of Abnormal Child Psychology, 12*, 1–14.

Hammes, J. (1978). *Stroop-Kleur-Woord-Test.* Lisse: Swets & Zeitlinger.

Holborow, P., & Berry, P. (1986). A multinational, cross-cultural perspective on hyperactivity. *American Journal of Orthopsychiatry, 56*, 320–322.

Hooper, S.R., & Willis, W.G. (1989). *Learning disability subtyping.* New York: Springer.

Kelly, M.S., Best, C.T., & Kirk, U. (1989). Cognitive processing deficits in reading disabilities: A prefrontal cortical hypothesis. *Brain and Language, 11*, 275–293.

Lambert, N.M., & Sandoval, J. (1980). The prevalence of learning disabilities in a sample of children considered hyperactive. *Journal of Abnormal Child Psychology, 8*, 33–50.

Licht, R. (1989). Reading disability subtypes: Cognitive and electrophysiological differences. In D.J. Bakker & G. Van der Vlugt (Eds.), *Learning disabilities: Neuropsychological correlates and treatment.* Amsterdam/Lisse: Swets & Zeitlinger.

Licht, R., & Van Onna, J. (1995). Differences in components of word recognition between P- and L-type reading disability. In C.K. Leong & R.M. Joshi (Eds.), *Developmental and acquired dyslexia* (pp. 41–50). Netherlands: Kluwer Academic Publishers.

Logan, G.D., & Cowan, W.B. (1984). On the ability to inhibit thought and action: A theory of an act of control. *Psychological Review*, *91*, 295–327.

Logan, G.D., Cowan, W.B., & Davis, K.A. (1984). On the ability to inhibit simple and choice reaction time responses: A model and a method. *Journal of Experimental Psychology: Human Perception and Performance*, *10*, 276–291.

Lovett, M.W. (1984). A developmental perspective on reading dysfunction: Accuracy and rate criteria in the subtyping of dyslexic children. *Brain and Language, 22*, 67–91.

McGee, G., & Share, D.L. (1988). Attention deficit disorder-hyperactivity and academic failure: Which comes first and what should be treated? *Journal of the American Academy of Child and Adolescent Psychiatry, 27*, 318–325.

Milich, R., & Kramer, J. (1984). Reflections on impulsivity: An empirical investigation of impulsivity as a construct. In K.D. Gadow (Ed.), *Advances in learning and behavioral disabilities* (Vol. 3, pp. 57–94). Greenwich, CT: JAI.

Mitterer, J.O. (1982). There are at least two kinds of poor readers: Whole word readers and recoding poor readers. *Canadian Journal of Psychology, 36*, 445–461.

Morris, R.D., Stuebing, K.K., Fletcher, J.M., Shaywitz, S.E., Lyon, G.R., Shankweiler, D.P., Katz, L., Francis, D.J., & Shaywitz, B.A. (1998). Subtypes of reading disability: Variability around a phonological core. *Journal of Educational Psychology, 90*, 347–373.

Morton, J. (1979). Word recognition. In J. Morton & J.C. Marshall (Eds.), *Psycholinguistics* (Series 2, pp. 109–156). London: Elek.

Morton, J., & Patterson, K. (1980). A new attempt at an interpretation, or, an attempt at a new interpretation. In M. Coltheart, K. Patterson, & J.C. Marshall (Eds.), *Deep dyslexia* (pp. 91–118). London: Routledge and Kegan Paul.

O'Neill, M.E., & Douglas, V.I. (1991). Study strategies and story recall in attention deficit disorder and reading disability. *Journal of Abnormal Child Psychology, 19*, 671–692.

Oosterlaan, J. (2000). Behavioural inhibition and the development of childhood anxiety disorders. In W.K. Silverman & Ph.D.A. Treffers (Eds.), *Anxiety disorders in children and adolescents* (pp. 45–71). Cambridge: Cambridge University Press.

Oosterlaan, J., & Sergeant, J.A. (1998). Response inhibition and response re-engagement in attention-deficit/hyperactivity disorder, disruptive, anxious and normal children. *Behavioural Brain Research, 94*, 33–43.

Patel, T.K., & Licht, R. (2000). Verbal and affective laterality effects in P-dyslexic, L-dyslexic and normal children. *Child Neuropsychology*, *6*, 157-174.

Pennington, B.F., Grossier, D., & Welsh, M.C. (1993). Contrasting cognitive deficits in attention deficit hyperactivity disorder versus reading disability. *Developmental Psychology, 29*, 511–523.

Pennington, B.F., & Ozonoff, S. (1996). Executive functions and developmental psychopathology. *Journal of Child Psychology and Psychiatry, 37*, 51–87.

Pliszka, S.R., Borcherding, S.H., Spratley, K., Leon, S., & Irick, S. (1997). Measuring inhibitory control in children. *Developmental and Behavioral Pediatrics, 18*, 254–259.

Purvis, K.L., & Tannock, R. (2000). Phonological processing, not inhibitory control, differentiates ADHD and reading disability. *Journal of the American Academy of Child and Adolescent Psychiatry, 39*, 485–494.

Quay, H.C. (1988a). Attention deficit disorder and the behavioral inhibition system: The relevance of the neuropsychological theory of Jeffrey A. Gray. In L.M. Bloomingdale & J.A. Sergeant (Eds.), *Attention Deficit disorder: Criteria, cognition, intervention* (pp. 117–125). Oxford: Pergamon.

Quay, H.C. (1988b). The behavioral reward and inhibition system in childhood behavior disorder. In L.M. Bloomingdale (Ed.), *Attention deficit disorder* (Vol. 3, pp. 176–185). Oxford: Pergamon.

Rafal, R., & Henik, A. (1994). The neurology of inhibition: Integrating controlled and automatic processes. In D. Dagenbach & T.H. Carr (Eds.), *Inhib-*

itory processes in attention, memory, and language. San Diego: Academic Press.
Rutter, M. (1978). Prevalence and types of dyslexia. In A.L. Benton & D. Pearl (Eds.), *Dyslexia: An appraisal of current knowledge* (pp. 3–28). New York/London: Oxford University Press.
Satz, P., & Morris, R. (1981). Learning disabilities subtypes: A review. In F.J. Pirozzolo & M.C. Wittrock (Eds.), *Neuropsychological and cognitive processes in reading* (pp. 109–141). New York: Academic Press.
Schachar, R., & Logan, G.D. (1990). Impulsivity and inhibitory control in normal development and childhood psychopathology. *Developmental Psychology*, *26*, 710–720.
Sergeant, J.A., Van Velthoven, R., & Virginia, A. (1979). Hyperactivity, impulsivity and reflectivity: An examination of their relationship and implications for clinical child psychology. *Journal of Child Psychology and Psychiatry, 20*, 47–60.
Shallice, T. (1982). Specific impairments of planning. *Philosophical Transactions of the Royal Society of London, B, 298*, 199–209.
Shaywitz, B.A, Fletcher, J.M., & Shaywitz, S.E. (1994). Defining and classifying learning disabilities and attention-deficit/hyperactivity disorder. *Journal of Child Neurology, 10* (Supp. 1), 50–57.
Shaywitz, B.A., Fletcher, J.M., Holahan, J.M., Shneider, A.E., Marchione, K.E., Stuebing, K.K., Francis, D.J., Shankweiler, D.P., Katz, L., Liberman, I.Y., & Shaywitz, S.E. (1995). Interrelationships between reading disability and attention-deficit/hyperactivity disorder. *Child Neuropsychology, 1*, 170–186.
Shue, K.L., & Douglas, V.I. (1992). ADHD and the frontal lobe syndrome. *Brain and Cognition, 20*, 104–124.
Silver, L. (1981). The relationship between learning disabilities, hyperactivity, distractibility, and behavioral problems. *Journal of the American Academy of Child Psychiatry, 20*, 385–397.
Stanovich, K.E., Siegel, L.S., & Gottardo, A. (1997). Converging evidence for phonological and surface subtypes of reading disability. *Journal of Educational Psychology, 89*, 114–127.
Stroop, J.R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18*, 643–662.
Struiksma, A.J.V., Van der Leij, A., & Vieijra, J.P.M. (1989). *Diagnostiek van technisch lezen en aanvankelijk spellen* [Diagnostics of technical reading and early spelling ability]. Amsterdam: VU Uitgeverij.
Treisman, A.M. (1960). Contextual cues in selective listening. *Quarterly Journal of Experimental Psychology, 12*, 242–248.
Van Aarle, E.J.M., & Volleberg, M.J. (1986). Raders en spellers: Wat is de betekenis van dit onderscheid in de groep zwakke lezers? *Pedagogische Studiën, 63*, 339–346.
Van den Berg, R.M., & Te Lintelo, H.G. (1977). *AVI-pakket* [The AVI-system]. Den Bosch: KPC.
Van der Leij, D.A.V. (1983). *Ernstige leesproblemen.* Lisse: Swets & Zeitlinger.
Van Strien, J.W., Bakker, D.J., Bouma, A., & Koops, W. (1990). Familial resemblance for cognitive abilities in families with P-type dyslexic, L-type dyslexic, or normal reading boys. *Journal of Clinical and Experimental Neuropsychology, 12*, 843–856.
Van Strien, J.W., Bouma, A., & Bakker, D.J. (1993). Lexical decision performances in P-type dyslexic, L-type dyslexic and normal reading boys. *Journal of Clinical and Experimental Neuropsychology, 15*, 516–524.
Van Strien, J.W. (1999). Verbal learning in boys with P-type dyslexia, L-type dyslexia and boys without learning disabilities: Differences in learning curves and in serial position curves. *Child Neuropsychology, 5*, 145–153.
Willcutt, E.G., & Pennington, B.F. (2000). Comorbidity of reading disability and attention-deficit/hyperactivity disorder: Differences by gender and subtype. *Journal of Learning Disabilities, 33*, 179–191.
Winer, B.J. (1971). *Statistical principles in experimental design.* Tokyo: McGraw-Hill Kogakusha.